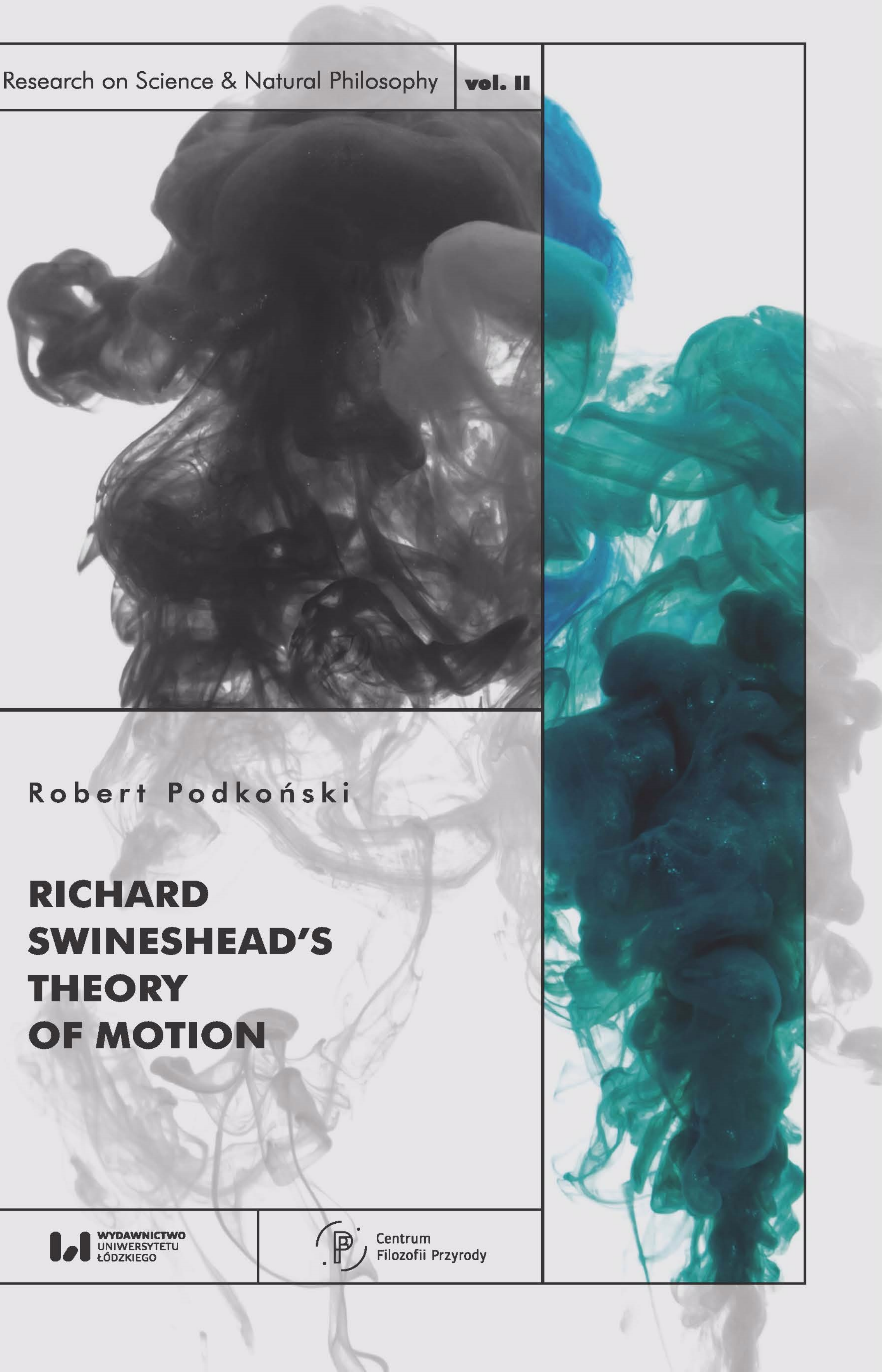

Research on Science & Natural Philosophy **vol. II**

Robert Podkoński

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Wydawnictwo Uniwersytetu Łódzkiego
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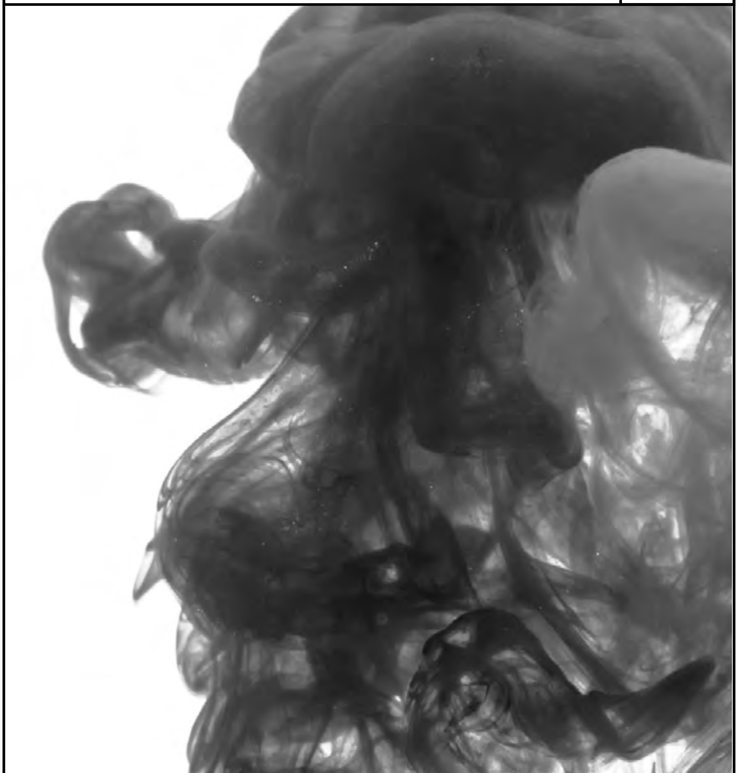

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Łódź 2019

Centrum Filozofii Przyrody

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Introduction

Historians of later medieval science agree that the "Book of calculations" (*Liber calculationum*) attributed to a certain Richard Swineshead marks the summit, and – at the same time – the final stage in the development of natural philosophy at the so-called Oxford Calculators' school.[1] The sobriquet of the above mentioned author, "the Calculator," one commonly employed by later thinkers and equally the editors of his monumental treatise, served in fact as the basis for the establishment of the name for this informal group of English natural philosophers: famous for introducing the mathematical procedures into Aristotelian physics.[2] The fourteenth-century scholars recognized as members of the Oxford Calculators' school were interested in an array of natural philosophical problems, ranging from the intension and remission of primary and secondary qualities, through the problem of reaction, to determining the "value" of the action of light sources, for example. What makes their discussions and treatises belong to the "calculatory" tradition is the context or need to "measure" or determine the range of the changes described in terms

1 See, M. Clagett, *Richard Swineshead and Late Medieval Physics*, "Osiris", 9(1950), 131—161; J.E. Murdoch, E.D. Sylla, *The Science of Motion*, in: *Science in the Middle Ages*, D. Lindbergh, ed., University of Chicago Press, Chicago 1978, 227; E.D. Sylla, *The Oxford Calculators*, in: *The Cambridge History of Later Medieval Philosophy*, N. Kretzmann, A. Kenny, J. Pinborg, eds., Cambridge University Press, Cambridge 1982, 540, 555; L. Thorndike, *A History of Magic and Experimental Science*, Vol. III, Columbia University Press, New York 1934, 370—371.

2 For example, we find the epithet "Calculator" on the title page of the Venice 1520 edition of the "Book of Calculations," by Victor Trincavellus. Also, Gottfried Wilhelm Leibniz in his letter to Thomas Smith of January 29, 1697, refers to this sobriquet, announcing that: "Vellem etiam edi scripta Joh. Suiseth, vulgo dicti Calculatoris, qui Mathesin in philosophiam scholasticam introduxit". G.W. Leibniz, *Sämtliche Schriften und Briefe*, Bd. 13, Akademie – Verlag, Berlin 1987, 513. For more details on the Venice 1520 edition of the treatise and on the different first names of the author appearing in the manuscript copies, as well as in the printed editions of the "Book of Calculations," see R. Podkoński, *Richard Swineshead's* Liber calculationum *in Italy. Some Remarks on Manuscripts, Editions and Dissemination,* "Recherches de Théologie et Philosophie médiévales," LXXX, 2(2013), 308—309, 331—334. The above-mentioned group of Oxford thinkers was first called the "Mertonians" by such renowned scholars as, among others, Anneliese Maier, Marshall Clagett or James Weisheipl, since many of these medieval authors had been fellows of Merton College, Oxford, but Edith D. Sylla has provided sufficient arguments in favour of using rather the "Oxford Calculators" name with regard to them. See, E.D. Sylla, *The Oxford Calculators*, 540—541.

of ratios and proportions.[3] This new method of analytical inquiry adopted to a greater or lesser extent by fourteenth-century Oxford natural philosophers, was a type of calculus (*calculationes*) based on the Eudoxean-Euclidean theory of proportions derived chiefly from Book V of the "Elements".[4]

From the modern point of view the most important and, according to certain historians of science, the most influential part of the Oxford Calculators' achievements in natural philosophy were their conclusions concerning local motion. The so-called "mean speed theorem" (known also as the "Merton rule") is often acknowledged as this school's most significant contribution to the development of later medieval, or even early modern physics.[5] There is no doubt whatsoever as to the ingenuity of William Heytesbury, who first formulated this theorem in his *Regulae solvendi sophismata* ("Rules for solving sophisms"), but the belief over its significance for the early modern science is now somewhat discarded.[6] Most probably the hypothesis suggesting the direct influence of Heytesbury's theorem on the formation of modern physics was partially dictated by the similarity – external in fact – of the graphical representation of this theorem to be found in the early printed edition of his treatise and the diagram employed by Galileo in his "Dialogue" to explain the constant acceleration in free fall motion.[7] The question of the possible influence of later medieval natural philosophy on the early stages of modern science is still open and disputable, but since it is far beyond the scope of this publication, I will leave it as an aside.

This notwithstanding, for the thinkers we have in mind when speaking about the Oxford Calculators, the "science of local motion" was surely the first and the most important part of natural philosophy. It was commonly accepted

3 All the mentioned topics are widely discussed in the "Book of Calculations," as well as in the other Oxford Calculators' works. The summary of the contents of the *Liber calculationum* is given in: J.E. Murdoch, E.D. Sylla, *Swineshead (Swyneshed, Suicet, etc.), Richard (fl. ca. 1340—1355)*, in: *Dictionary of Scientific Biography*, Vol. 13, C.C. Gillispie, ed., Charles Scribner's Sons, New York 1976, 187—206.

4 See, E.D. Sylla, *The Oxford Calculators*, 553.

5 See, e.g. A.C. Crombie, *Medieval and Early Modern Science*, Vol. II: *Science in the Later Middle Ages and Early Modern Times: XIII—XVII centuries*, Doubleday & Company, Inc., Garden City, New York 1959, 85—97; E. Moody, *Laws of Motion in Medieval Physics*, in: *Studies in Medieval Philosophy, Science, and Logic. Collected Papers 1933—1969*, University of California Press, Berkeley—Los Angeles—London 1975, 195—197.

6 On the "mean speed theorem" and William Heytesbury, see chapter 1.5 below.

7 See, e.g. A.C. Crombie, *op. cit.*, 145—147; C.B. Boyer, *The History of the Calculus and its Conceptual Development (The Concepts of the Calculus)*, Dover Publications Inc., New York 1959, 82—83.

within fourteenth-century scholastic philosophy that the fundamental subject of physics, as defined by Aristotle himself, is motion, since:

> Nature has been defined as a 'principle of motion and change,' and it is the subject of our inquiry. We must therefore see that we understand the meaning of 'motion'; for if it were unknown, the meaning of 'nature' too would be unknown.[8]

The term 'motion' was understood here broadly, as any kind of temporal, continuous change, be it alteration, augmentation or local motion, but still Aristotle declared unambiguously that:

> motion in space [i.e., local motion] is the first of the kinds of change.[9]

We are fortunate enough to have access to a substantial number of the Oxford Calculators' extant works on local motion, ranging from the earliest, i.e., Richard Kilvington's questions on "Physics" (1325) where the "new – i.e., mathematically and logically consistent – rule of motion" is first proposed and employed, through Thomas Bradwardine's *Tractatus proportionum seu de proportionibus velocitatum in motibus* (1328, "The treatise on proportions, or about proportions between speeds in motions") and William Heytesbury's *De motu locali* chapter of his "Rules for solving sophisms" (1335, *Regulae solvendi sophismata*), to treatise XIV of Richard Swineshead's "Book of calculations": "On local motion," finished before 1350. Each of the mentioned authors recognized the problem of the proper description of local motion as fundamental for natural philosophy. Richard Kilvington, reinterpreting the "rules" of local motion that are to be found in the last chapter of Book VII of Aristotle's "Physics" in terms of geometrical proportionality managed to avoid the contradictory conclusions that stem from these statements.[10] Thomas Bradwardine's treatise is a well thought over and diligently composed handbook, the declared purpose of which was to avoid the "clouds of ignorance" and allow the truth to "shine brightly enlightened by the science" while presenting

8 Aristotle, *Physics*, 200b12—14, Bk. III: Ch. 1, R.P. Hardie, R.K. Gaye, transl., in: *The Basic Works of Aristotle*, R. McKeon, ed., The Modern Library, New York 2001, 253.

9 Aristotle, *Metaphysics*, 1072b9, Bk. XII: Ch. 7, W.D. Ross, transl., in: *The Basic Works of Aristotle*, 880.

10 See, E. Jung-Palczewska, *Richard Kilvington on local motion*, in: *Chemins de la pensée médiévale. Etudes offertes à Zénon Kaluza*, P.J.M.M. Bakker, ed., Brepols 2002, 128—130.

the "new rule of motion" and its consequences in the systematic manner.[11] William Heytesbury in his handbook "Rules for solving sophisms" in presenting the problem of natural changes, i.e., alteration, augmentation and local motion, states unambiguously at the very beginning of this section that "local motion by nature precedes other kinds [of change] just as the first".[12] When considered against the remaining parts of the "Book of calculations," the treatise "On local motion" is undoubtedly fundamental for the whole book, being referred to most often in its other sections.[13] The treatise itself features the "geometrical" method of scientific inquiry, obviously imitating the axiomatic structure of Euclid's "Elements". Richard Swineshead included here 58 consecutive "rules" (*regulae*) or "conclusions" (*conclusiones*) derived either as the logical consequences of the first assumption that "motion is measured in terms of geometrical proportion" or, where possible, from precedent, already proven statements.[14] Few of these, like "mean speed theorem," that is to be found here too and in no fewer than four different formulations, were employed by Richard Swineshead himself in the other sections of his "Book of calculations" in quite different contexts like, for example, the problem of the induction of the highest degree of an elementary, primary quality, such as heat.[15] Surely, with his treatise *De motu locali* "The Calculator" had reached the limits of what could be possibly and properly described with regard to

11 <Thomas Bradwardinus,> *Tractatus proportionum, seu de proportionibus velocitatum in motibus*, in: *Thomas Bradwardine, his Tractatus de Proportionibus; its significance for the development of mathematical physics*, H. Lamar Crosby Jr., ed., University of Wisconsin Press, Madison (WI) 1955, 110: "His ergo ignorantiae nebulis demonstrationum flatibus effugatis, superest ut lumine scientiae resplendeat veritas." (Further referred to as: Thomas Bradwardinus, *Tractatus de proportionibus*).

12 Guilelmus Heytesbury, *Regulae solvendi sophismata*, Venetiis 1494, f. 37ra: "motus localis naturaliter precedit alios tamquam primus." (Translations from Latin into English are all mine, unless noted otherwise – R.P.) The mentioned section of Heytesbury's work, dealing with the problem of the "measurement" of qualitative and quantitative changes is often referred to as "De tribus predicamentis" in the secondary literature. For the sake of brevity I will adopt this title in the following sections of this book.

13 See, R. Podkoński, *Suisetica inania. Ryszarda Swinesheada spekulatywna nauka o ruchu lokalnym*, Wydawnictwo Uniwersytetu Łódzkiego, Łódź 2017, 135—139.

14 Ricardus Swineshead, *Liber calculationum: Tractatus de motu locali*, § 1: "Supponendo motum attendi penes proportionem geometricam quedam hic de motu locali regule exarantur," in: R. Podkoński, *Suisetica inania*, 271. Cf. also, 45—122; J.E. Murdoch, E.D. Sylla, *Swineshead*, 201—204.

15 See, R. Podkoński, *Suisetica inania*, 136—137.

local motion employing the axiomatic, purely speculative method of *calculationes* within the scope of Aristotelian natural philosophy.[16]

Concerning Richard Swineshead's accounts on local motion we are even more fortunate, having access to his two other extant works on this topic, namely to the short treatises *De motu* ("On motion") and *De motu locali* ("On local motion").[17] Preserved are two manuscript copies of the latter text and three of the former.[18] Of course, the authorship of these *opuscula* is not absolutely certain, being based primarily on the *explicit* note to be found in the Cambridge copy of the texts.[19] Still, we can safely assume that the author of these short treatises was the same person who wrote the "Book of calculations".[20] Arguments in favour of this hypothesis will be presented below together with a detailed description of the contents, sources and the relationship of the *opuscula* to the treatise "On local motion" included in the "Book of calculations". Since the manuscript sources are not readily accessible, even to researchers, not to mention their proneness to further deterioration, I decided to prepare the critical Latin edition of Richard Swineshead's short treatises on motion, which is included in the present tome. I strongly believe that my edition will give historians of medieval and early modern science a much better insight into the lesser known works on local motion, when compared to *Liber calculationum* of course, ascribed to Richard Swineshead. John Murdoch and Edith Sylla have already stated that these *opuscula* should be seen as successive drafts or

16 See, *ibid.*, 123—131.

17 The titles of these treatises, as well as their autorship, were established by John Murdoch and Edith Sylla in their presentation of Swineshead's works in *The Dictionary of Scientific Biography*. The title of the latter text is based on the *explicit* of the manuscript copy of these short treatises preserved in the codex Cambridge, Gonville & Caius 499/268, f. 215rb that reads: "Explicit tractatus de Swynyshed de motu locali," while the title of the former refers to its fundamental topic, as explicitly declared: "Et quia inter alios motus localis perfectissimus est et primus quia corpori perfecto firmamen competit, de ipso primo considerande sunt regule prime". Cf. Ricardus Swineshead, *Opusculum de motu*, § 9, below. Cf. J.E. Murdoch, E.D. Sylla, *Swineshead*, 206—207.

18 Both these short treatises are to be found in the manuscript codices: ms. Cambridge, Gonville & Caius 499/268, fols. 212ra—215rb, and ms. Seville, Bibl. Colombina 7–7–29, fols. 28va—33rb, and the third preserved, but in a very poor state, copy of the *opusculum* "On motion" is to be found in the codex ms. Oxford, Digby 154, fols. 42ra—44ra. See *Introduction* to the critical edition of these short treatises included in this tome, below.

19 See note 17 above.

20 J.A. Weisheipl, J.E. Murdoch and E.D. Sylla were all convinced that Richard Swineshead should be regarded as the author of these *opuscula*. Cf. J.A. Weisheipl, *Ockham and Some Mertonians*, "Mediaeval Studies," 30(1968), 219—221; J.E. Murdoch, E.D. Sylla, *Swineshead*, 185.

steps taken by the Calculator on his way to construct a complete, speculative science of local motion.[21] Anticipating some conclusions drawn and presented in detail below, I am convinced that these short treatises on motion should be also seen as the direct link between William Heytesbury's *De motu locali* and the above-mentioned section "On local motion" of Swineshead's "Book of calculations". In this regard these texts are the perfect testimony to the vivid development of the speculative science of local motion within the intellectual milieu of the Oxford Calculators.[22]

In order to establish firm grounds for the above hypothesis in what follows in the first chapter of this monograph I try to answer the question as to why fourteenth-century Oxford natural philosophers, namely Richard Kilvington and Thomas Bradwardine, found it important and worthwhile to reformulate Aristotle's science of local motion constructing and employing the method of the *calculationes*. For the purpose I include a short *résumé* of Aristotle's statements and "rules" regarding local motion, emphasizing the dubious and mutually inconsistent points in his theory. A need to clear up and correct these can be undoubtedly assumed as the most obvious motivation for Kilvington and Bradwardine. On the other hand, the very way the Aristotle's "rules" of local motion themselves were formulated could have dictated to these authors the need to make reference to the calculus of ratios.

Also the intellectual context in the development of natural philosophy at Oxford University at the beginning of the fourteenth century is sketched there, with special emphasis on the influence of Robert Grosseteste's and William Ockham's theories and statements. The former, one of the founders of Oxford University and its first Chancellor, was strongly convinced that mathematics was the perfect tool for unveiling the secrets of nature, since he believed that the real world was at its very core created according to mathematical rules, i.e., specifically the geometrical laws of optics. The latter author, mostly famous for his "Razor", reformulated Aristotelian methodology of sciences and its restrictions in such a way that introducing mathematical tools of analysis into natural philosophical issues was no longer seen as wrong or fallacious.

Further on in the same chapter the birth and development of the Oxford Calculators' science of local motion is described in brief. The context for the

21 J.E. Murdoch, E.D. Sylla, *Swineshead*, 206.

22 Some of the conclusions I present below are also discussed in my article: R. Podkoński, *The Opuscula de motu ascribed to Richard Swineshead. The testimony of the ongoing development of the Oxford Calculators' science of motion*, in: *Quantifying Aristotle. The Impact, Spread, and Decline of the* Calculatores *tradition*, D.A. DiLiscia, E.D. Sylla, eds., Leiden—Boston *et al.*, Brill, forthcoming.

formulating of the “new rule of motion” is presented with references to Richard Kilvington’s and Thomas Bradwardine’s specific statements. Next the section scrutinises William Heytesbury’s *De tribus predicamentis* section: “On local motion”, not only with regard to the “mean speed theorem” formulated there, but also with reference to his innovative and potentially inspiring ideas and conclusions.

The second chapter of this monograph is devoted to a presentation of the *opuscula* on motion ascribed to Richard Swineshead. The contents of these short treatises are described against the background of the development of the Oxford Calculators’ science of local motion, accentuating the adopted concepts and sometimes explicitly quoted statements drawn from Richard Swineshead’s predecessors. Also, I attempt to unravel the conundrum regarding the mutual relation between these two texts and establish the temporal order they were written in. Interestingly enough, in fact there are two substantially, but not wholly different versions of the *Opusculum de motu* preserved in manuscript copies, a circumstance that makes the mentioned conundrum rather more complicated. One of these versions features, surprisingly enough, much more obvious similarities to the certain rules included in the treatise “On local motion” from the “Book of calculations” than the other, not mentioning the second *opusculum* considered here. These similarities, nevertheless, when taken together with other issues of significance allow us to assume that both short treatises on motion can be safely considered to be Richard Swineshead’s succesive attempts at constructing a complete, speculative science of local motion.

Finally, I briefly present the subsequent development of Richard Swineshead’s science of local motion. Chapter XIV of his “Book of calculations”: *De motu locali*, is concisely described and summarized here in order to give the reader the insight into its contents and to present the degree of its scientific and methodological sophistication. Here are compared all the preserved texts on local motion ascribed to Swineshead, while formulated are some general conclusions about the development of “the science of motion” in later medieval Oxford natural philosophy.

The critical edition of both short treatises on local motion ascribed to Richard Swineshead included in this tome was prepared on the basis of all the known extant manuscript copies of these texts. In the introduction to this edition I present a detailed description of the codices in which they are to be found as well as the editorial rules I have observed. Also, there are formulated a few conclusions on the mutual relationship between these manuscript copies.

Chapter 1

The development of the Oxford Calculators' science of local motion

1.1. Sources of inspiration for fourteenth-century mathematical natural science

In regarding the presentation of any of the issues discussed by Oxford medieval natural philosophers one should always refer first to the theories developed by Robert Grosseteste (1168—1253), bishop of Lincoln and the University's first chancellor, "the real founder of the tradition of scientific thought in medieval Oxford" – as he has been described by one of the most influential historians of science, Alistair Crombie.[1] Grosseteste is perhaps better known in the history of philosophy thanks to his original cosmological and cosmogonical speculations, aptly described in the secondary literature as the "metaphysics of light". In short, Grosseteste advanced the idea that the whole universe in its very beginning, that is at the moment of Creation, emanated from the first indivisible and infinitely small point of light (*lux*) that multiplicated itself *in infinitum* in every direction, thus constituting spherical, finite cosmic space. This primordial light was defined by Grosseteste as the first corporeal form (*forma prima corporalis*). The resulting, secondary light (*lumen*) emanating from the cosmic sphere towards the centre of the universe was the factor that produced the elementary matter. This process, described quite perfunctorily and not clearly by Grosseteste, was to occur as a result of the condensation and rarefaction of the *lumen*.[2] His most influential statement given the context of

1 A.C. Crombie, *op. cit.*, 11—12. Cf. also, G. Beaujouan, *Medieval Science in the Christian West*, in: *Ancient and Medieval Science*, R. Taton, ed., London 1963, 491. On the biography, works and philosophy of Robert Grosseteste, see: N. Lewis, *Robert Grosseteste*, in: *The Stanford Encyclopedia of Philosophy* (Summer 2019 Edition), Edward N. Zalta, ed., https://plato.stanford.edu/archives/sum2019/entries/grosseteste/ (accessed: 10.07.2019).

2 <Robertus Grosseteste,> *Tractatus de luce secundum Lincolniensem* (further quoted as *De luce*), in: *Robert Grosseteste and His Intellectual Millieu. New Editions and Studies,* J. Flood, J.R. Ginther, J.W. Goering, eds., Pontifical Institute of Medieval Studies, Toronto 2013, 226—238.

the later development of Oxford medieval natural philosophy was, however, that this process took its course according to the geometrical laws of optics and katoptrics. Consequently, the structure of the created, physical world conformed necessarily to the laws of geometry.[3]

The idea that the laws of nature are mathematical in their essence was the main concept of Robert Grosseteste's natural philosophy, something inherited by subsequent generations of medieval English scholars. His detailed description of the natural world was soon superseded by the Aristotelian worldview, what was an inevitable result for the Latin-speaking world of the rediscovery of Aristotle's natural philosophical works.[4] Still, "the special importance [given] to mathematics in attempting to provide a scientific explanation of the physical world" was the ever present distinguishing feature of Oxford medieval natural science.[5] No wonder, then, that the application of *calculationes* to Aristotle's own assumptions concerning the relations between forces, resistances and speeds in local motions was first undertaken by English thinkers. It is worth noting here that the form these relations were formulated in his *Physics* actually could also suggest reference to the calculus of ratios in order to explain or interpret them consistently.

1.2. "Mathematical rules" of local motion in Aristotle's physics

In the final section of Book VII of his *Physics,* Aristotle formulated the relations of factors involved in local motions in the following manner:

> If, then, a the movent have moved b a distance c in a time d, then in the same time the same force a will move ½ b twice the distance c, and in ½ d it will move ½ b the whole distance c: for thus the rules of proportion will be observed. Again, if a given force move a given weight a certain distance in a certain time and half the distance in half the time, half the motive power will move half the weight the same distance in the same

3 Robertus Grosseteste, *De lineis, angulis et figuris*, in: *Die Philosophischen Werke des Robert Grosseteste, Bischofs von Lincoln*, Ludwig Baur, ed., Aschendorff Verlag, Münster 1912.

4 B.G. Dod, *Aristoteles Latinus*, in: *The Cambridge History of Later Medieval Philosophy,* 69—74.

5 A.C. Crombie, *Grosseteste's Position in the History of Science*, in: *Robert Grosseteste: Scholar and Bishop*, Daniel A. Callus, Clarendon Press, Oxford 1955, 111.

> time. Let e represent half the motive power a and f half the weight b: then the ratio between the motive power and the weight in the one case is similar and proportionate to the ratio in the other, so that each force will cause the same distance to be traversed in the same time.[6]

At first sight everything seems obviously correct. "Common sense" tells us that if a motive force a can move some weight b in a distance c, then the same force will move half the weight b for twice the distance in the same time, or will traverse the distance c in half the time, i.e., it will move b twice faster. Similarly, the force that is half the force a will move half the weight b for the same distance c in the same time, since the ratio of force to weight is the same in this case. Further on, however, the relations between these factors become less straightforwardly simple:

> But if e move f a distance c in a time d, it does not necessarily follow that e can move twice f half the distance c in the same time. If, then, a move b a distance c in a time d, it does not follow that e, being half of a, will in the time d or in any fraction of it cause b to traverse a part of c the ratio between which and the whole of c is proportionate to that between a and e (whatever fraction of a e may be): in fact it might well be that it will cause no motion at all; for it does not follow that, if a given motive power causes a certain amount of motion, half that power will cause motion either of any particular amount or in any length of time (…).
>
> If on the other hand we have two forces each of which separately moves one of two weights a given distance in a given time, then the forces in combination will move the combined weights an equal distance in an equal time: for in this case the rules of proportion apply.[7]

Thus, when the weight is doubled, the same motive force would not necessarily move it at all, even though the ratio between the factors remains the same. In turn, this is the consequence of the another "common sense" condition introduced by Aristotle in the context of his refutation of the existence of void space in the natural world.

6 Aristotle, *Physics*, 250a2—9, Bk. VII, ch. 5, 353.

7 *Ibid.*, 250a10—28, 352—353.